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Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of	)	MM Docket No. 87-268
Advanced Television Systems and	)	
Their Impact on the Existing	)	
Television Broadcast Service.	)	

COMMENTS OF THE DAVID SARNOFF RESEARCH CENTER, INC.

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INTRODUCTION

The David Sarnoff Research Center, Inc. (formerly RCA Laboratories) is engaged in the design and development of improved and advanced television systems for the United States and therefore has a major interest in the issues raised by the Federal Communication Commission's (FCC) Notice of Inquiry (Inquiry) in MM Docket No. 87-268.

Established in 1942 as RCA Laboratories and reorganized in April 1987 as a subsidiary of SRI International, the David Sarnoff Research Center continues to study ways to improve the U.S. television system and brings to its Comments views developed by it and its predecessor company over five decades of work.

The issues raised in the Inquiry are very complex. At this time the technical foundation required to answer many of these questions is insufficient. The David Sarnoff Research Center strongly supports a thorough study of Advanced Television (ATV) and its impact on television broadcast services and spectrum allocation. This study should include technical analyses and tests to form the basis for decisions regarding standards and spectrum allocations.

The United States is on the threshold of improved quality television. Technology, including displays, semiconductors, digital signal processors, and memory technologies, is largely in place to make this possible. Despite the extraordinary commercial success of the National Television Systems Committee (NTSC) standard, technological advances make higher resolution and wider aspect ratio systems both desirable and economically feasible.

Sufficient VHF and UHF spectrum must be provided for future High Definition Television (HDTV) broadcast systems. The present NTSC system can be thought of as a "five picture height" system. This means that, at a viewing distance of five times the height of the screen, it produces excellent images with no noticeable defects. It also means that, at a distance of five picture heights, the human visual system is just capable of resolving all the detail presented. Studies[1] show that a single-channel, compatible system resulting in similar perceptual performance at "three picture heights" should suffice for the U.S. for the next ten to fifteen years. However, additional spectrum will be needed for a future "one picture height" system. The FCC must assure that enough spectrum will be available to provide all broadcasters with additional bandwidth.

Additional useful UHF spectrum can be created by eliminating some of the so-called UHF taboos. Double-conversion UHF tuner technology, which eliminates several taboos, is available at modest TV receiver cost increases. The additional spectrum that will thus become available should provide for future HDTV needs. A study of appropriate relaxations of the UHF taboos should be begun as soon as possible.

Advanced television in the U.S. should be evolutionary and backward receiver-compatible at each step. Non-compatible systems are wasteful of spectrum since conventional NTSC service would have to be maintained concurrently with any such new service in order to avoid obsoleting the 140 million television sets currently in use. Compatible systems, on the other hand, avoid the need for additional spectrum. Based upon the surprisingly long continuing sales of black-and-white television receivers, sales of NTSC products can be expected to continue for at least twenty years after the introduction of a new ATV system. An evolutionary system allows increased performance that matches both practical display developments and realistic consumer price expectations. The consumer votes with his pocketbook in the final analysis, and the adopted system must be consistent with that process.

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1 Curtis R. Carlson and James R. Bergen, "Perceptual Considerations for High-Definition Television Systems," *SMPTE Journal*, Dec. 1984 Issue, Volume 93, Number 12.

The David Sarnoff Research Center is developing a fully receiver-compatible, single-channel, 5 x 3, extended definition television system which is called Advanced Compatible Television (ACTV). This system, which is being developed in support of NBC and GE/RCA Consumer Electronics, is described further in this document and has been demonstrated widely over the past six weeks. ACTV is a "three picture height" system with the resolution to produce high quality images that match the viewer's perceptual capability when viewed at three picture heights. A standard NTSC receiver would continue to produce a standard NTSC image when the new ACTV signal begins service.

The David Sarnoff Research Center is presently developing an augmentation strategy for ACTV using additional bandwidth. A "three picture height" system is not sufficient for the long term. The goal is to evaluate the image improvement possible with both 3 and 6 MHz of additional, possibly non-contiguous, bandwidth and to use this augmentation approach to produce and demonstrate a "one picture height" system.

This evolutionary strategy has many benefits which make it the best approach for all concerned parties: 1) for the broadcaster and cable operator it provides operational simplicity and lowest cost; 2) for set manufacturers it brings rapid adoption of service to drive sales of higher value-added, larger screen size TV receivers and new VCRs; 3) for the consumer it provides a heightened viewing experience more akin to a theater and appropriate for the 30-50" screen diagonals that will grow in popularity over the next ten to fifteen years. A system to accomplish this can be available at reasonable cost over all forms of signal delivery to the home: broadcast, cable, VCR, and DBS.

The switch to ACTV can occur more rapidly than to other proposed ATV systems because it is single channel and receiver-compatible and because it does not require extra bandwidth or additional transmitters. Provided that adequate VHF and UHF broadcast spectrum is available, augmented

ACTV can be implemented at the rate that display technology progresses, even to the point where floor-to-ceiling displays become economically feasible. This will likely be consistent with the timing of the phase-out of UHF taboos, which will make additional spectrum available for HDTV purposes. It is difficult to predict in 1987 just when a "one picture height" system will be feasible for the consumer. The evolutionary strategy eliminates the need to make that decision now and permits the transition to take place naturally.

This Introduction has summarized the David Sarnoff Research Center's position on Advanced Television for the United States. This position is more fully developed and supported in the main body of this document. In the following sections of this response, we comment on the specific questions in the Inquiry.

QUESTIONS ON ADVANCED TELEVISION SYSTEMS

1. What criteria, such as video/audio quality performance, transmission bandwidth, NTSC compatibility, etc., should the Commission use to evaluate and compare the various ATV technologies? What are the appropriate trade-offs between the various criteria?

The Commission should evaluate ATV system proposals using the following criteria:

1. Performance
2. Cost
3. Bandwidth requirements
4. NTSC receiver compatibility

The Commission should apply these criteria to the various proposals for improved image quality (as measured by aspect ratio, resolution, and reduction of defects) and improved audio quality (as measured by frequency response, distortion, SNR, dynamic range, and stereo separation). Although digital terrestrial broadcasting of audio may be feasible and cost effective in the future, digital technology *per se* should not be a system figure of merit.

The analysis should consider the consumer purchase costs of new ATV equipment and the costs to broadcasters and other suppliers of video signals to implement a new ATV system. Some ATV systems inherently permit a more orderly and easily understood transition to the new service. The Commission should consider the very large costs that will be borne by providers of TV hardware and ATV programming if marketplace confusion slows the sales of their products.

Consumer cost for the complete ATV system will weigh heavily in its acceptance because an ATV system will succeed in the marketplace only if it has sufficient perceived value. When calculating the total cost, the

Commission should consider that consumers will probably receive ATV signals through more than one medium and that these media will include terrestrial broadcast, cable, tape, and possibly satellite ATV signals. An ATV system that can be delivered by all major delivery systems is likely to result in the lowest ultimate cost to the consumer because it will have the largest manufacturing volume of receivers.

The cost to the broadcaster must also be considered. Different proposals differ widely in the financial impact they will have on local broadcasters. Those requiring two transmitters would seem to be considerably more burdensome to broadcasters than single transmitter proposals.

No ATV system that would obsolete the 140 million NTSC television receivers currently in American homes should be authorized by the Commission. Of course, NTSC could always be delivered on a separate channel if a new ATV service were not receiver-compatible. The question that should be addressed to each ATV system proposal is, therefore, how many TV channels are required to deliver the new service and simultaneously to prevent the obsolescence of present-day TV sets. American consumers have roughly 50 billion dollars invested in their TV receivers.

2. *What changes in ATV technologies should be anticipated for the near future? For example, can ATV technologies be expected to develop so that the transmission bandwidth of a high resolution production source can be compressed to fit within 6 MHz channel without apparent loss of quality? At what stage is the development of an all-digital ATV system using digital signal processing and IC technologies?*

A new technology, known as Advanced Compatible Television, or ACTV, under development at the David Sarnoff Research Center, was recently announced. ACTV compresses enhanced resolution, wide aspect ratio images into a single 6 MHz channel while simultaneously maintaining receiver compatibility. Appendix A contains a paper which will appear in a future issue of the IEEE Transactions on Broadcasting, describing details of the ACTV system. This system uses new three-dimensional frequency interleaving techniques to achieve the greatest enhancement in picture information that has been proposed thus far for a single, 6 MHz channel, NTSC receiver-compatible system.

Compatibility is achieved by a combination of physical and perceptual concealment of the new information. The system can be upgraded with additional bandwidth to achieve even better picture and sound quality. The system itself does not require that this additional bandwidth be contiguous. Practical considerations, however, may make usage of non-contiguous bandwidth difficult for any system.

ACTV consists of two separable signals. One occupies a 4.2 MHz bandwidth; the other, referred to as a "helper signal," occupies 750 kHz of bandwidth. For terrestrial or cable transmission, the two signals are combined by quadrature modulation and sent as one vestigial sideband AM signal. For tape or satellite delivery, the system can be delivered by any of several known means for sending two signals -- one being wide band, and the other being relatively narrow band.

Audio quality is an important aspect of any ATV system. In the ACTV system, compact disk quality sound can be achieved by using an augmentation channel. However, the new multichannel television sound (MTS) standard can provide very good sound quality. No ATV system should materially degrade the MTS signal. In other words, a compatible system must not degrade its own sound, and no system should degrade the audio or video of adjacent channels. In the ACTV system, when quadrature modulating the picture carrier with the "helper signal," great care is taken to avoid damage to the MTS signal. MTS imposes strict limits on the allowable phase modulation of the visual carrier.

3. How quickly are developments of the various ATV technologies progressing? Which are now operational? Which are in prototype stage? Developmental stage? How long until these systems are realized?

Comments regarding progress of the various ATV transmission formats are restricted to ACTV. At this time it is the system about which the David Sarnoff Research Center feels fully qualified to comment -- both in terms of progress to date and future timetables.

ACTV has been modeled on the Digital Video Facility (DVF) computer at the David Sarnoff Research Center. Transmission path vicissitudes and certain transmitter and receiver non-linearities are being studied by computer simulation. Real-time hardware suitable for initial field testing is under construction and completion is expected in late 1988. With Commission approval, field testing could begin in early 1989.

A common issue for all systems is the consumers' demand for bright, high contrast displays. Display brightness and contrast less than that delivered by today's home receivers will not be acceptable. There is no known technology today for achieving a large HDTV direct view display with acceptable consumer brightness. Therefore, it seems inappropriate to rush into an HDTV broadcast system. A system that can be upgraded when advances in display technology occur is preferable. The resolution capabilities of ACTV can be met by existing picture tube technology over the next decade or two at consumer-acceptable brightness and cost.

4. What are the relative costs of these new transmission systems for programming producers? For broadcasters? For consumers?

The cost of program production can be shown to be approximately the same for any of the proposed systems. All of the proposed ATV delivery systems can be served by the proposed HDTV production standard.

ATV systems can be ranked in order of increasing cost to the broadcaster in the following way: Broadcasters will incur the lowest costs for any system that requires no change to the existing exciter and transmitter. Costs will then be confined to new studio equipment, such as cameras, VTRs, and signal-routing equipment within the broadcast plant. Exciter modifications will cost less than transmitter modifications. Transmitter modifications will cost less than a new transmitter. Multiple new transmitters will be the most expensive. Producing, storing, routing, or special effects on any advanced TV signals will require new equipment.

The cost of ATV for consumers will be dominated by several issues:

1. The cost of the display. Higher resolution ATV systems (HDTV) place an exponentially growing cost burden on the display for an advanced TV system. Higher resolution displays inherently cost more because of the higher precision required in each step of the manufacturing process. Higher resolution can be appreciated only at close viewing distances (in picture heights). Therefore, for the fixed-size viewing environments in consumers' homes, the desired display size increases with the resolution capability of an ATV system. Hence, for the dual reasons of increased manufacturing precision and the desire for larger displays, increasing the resolution capability of ATV systems places a rapidly growing cost burden on the ATV display.

2. The number of different ATV systems that a receiver will have to decode. Automatic recognition and switching among different systems will add significant cost and complexity to the receiver. The Commission, therefore, should promulgate a single ATV system.

3. The market penetration and, hence, sales volume of a given ATV system. Reasonably rapid growth of any new system is highly desirably for all concerned. Unit costs decrease rapidly with increases in volume.

4. The complexity of the receiver circuitry. All ATV systems will use complex digital signal processing techniques. Most use semiconductor memory to a greater or lesser

extent. The specific semiconductor cost to implement digital processing and data storage in an ATV system will not dominate the ATV cost to the consumer. Instead, display costs and the presence or absence of a requirement for multiple ATV decoders will dominate the cost to consumers.

5. *From a technical perspective, what are the advantages and disadvantages of augmenting the channel capacity of existing television assignments? What is the appropriate bandwidth for the augmentation channel? Must it be contiguous to the main channel?*

Better image and audio quality can be delivered with more bandwidth. Even with the high information density achieved by ACTV, more bandwidth will still provide better image and audio quality. It is not yet clear when display technology will make augmentation from Extended Definition Television (EDTV) to HDTV economically viable. The important issue is that it is not critical to forecast display technology growth with great precision if the Commission adopts a single 6 MHz receiver-compatible strategy for advanced TV over the next decade.

Augmentation choices are usually considered in 3 MHz increments. Six MHz of augmentation is likely all that will be used for home entertainment. Significant flexibility and ease of implementation would be achieved if this added bandwidth does not have to be contiguous.

It is stated elsewhere in these Comments that further studies are needed to evaluate the effect of augmentation channels on the protection requirements. An HDTV service will affect the channel protection requirements in at least two ways: 1) the consumers' expectation of picture quality will be higher, so less degradation will be tolerated, and 2) augmentation information may be spectrally quite different from NTSC. The propensity of the augmentation channel to interfere and its immunity from interference may be quite different from NTSC.

QUESTIONS ON USE OF EXISTING ALLOCATIONS

NOTE: Questions 6 and 7 are answered jointly below.

6. Should the Commission implement ATV service at UHF only or at both VHF and UHF in a comprehensive plan?

7. What are the technical and economic advantages and disadvantages of this spectrum option?

All signal delivery vehicles should be able to provide ATV service; therefore it follows that both VHF and UHF should be part of an ATV service. To exclude VHF would limit VHF broadcasters to sub-standard service. Toward this goal there should be developed a comprehensive plan for the use of the VHF and UHF spectrum for ATV. A suggestion for such a plan is outlined in the answer to the questions on UHF taboos.

8.a. How much additional bandwidth could be made available for ATV, and what would be the interference implications if the Commission:

> *Adjusted the co-channel interference protections ratio?*
>
> *Adjusted the adjacent channel protection ratio?*
>
> *Established standards to permit TV licensees to access a channel (or part of a channel) adjacent to their assignment?*

Co-channel protection ratios were established with a great deal of care. It is unlikely that they can be changed for broadcast of NTSC television at UHF and VHF unless the public can be persuaded to use better and more expensive antennas. It might be possible to relax the co-channel protection ratios if lower power is feasible for augmentation signals, but this requires a very thorough study as outlined in the answer to the questions on UHF taboos.

Changing adjacent channel protection ratios could possibly be done on a gradual basis, but not until a thorough study of the potential disturbances of radiation in the adjacent channel to reception of other channels has been completed.

No standards that permit licensees' access to adjacent channels should be established without a thorough study.

The answer to the questions on UHF taboos includes a proposal for a comprehensive review of the taboos. Permits for temporary experimental transmissions could be considered on a case-by-case basis, provided such wideband transmission causes no interference in reception of allocated television channels.

8.b. How much additional bandwidth could be made available for ATV, and what would be the interference implications if the Commission modified or eliminated some or all of the UHF taboo channel protection standards?

This is addressed in the section on UHF Taboos following Question 16.

8.c. How much additional bandwidth could be made available for ATV, and what would be the interference implications if the Commission "repacked" the VHF and UHF spectrum using adjusted protection criteria to accommodate (for example) 9, 10, or 12 MHz-wide channels?

The effects of NTSC standard signals at present allocations are quite well understood regarding their interference with each other and other services. The effects of repackaged signals, say with 9, 10, or 12 MHz bandwidths, however, are unknown. A comprehensive computer program for spectrum allocation could be created and used to explore "what if" situations given a need and service specification.

If the VHF and UHF spectrum were repacked, the following system issues would have to be studied carefully:

- channel-to-channel relationships
- noise differences, if a service is to be split between two bands
- cost to present broadcasters to change frequencies
- impact on cable
- impact on and from adjacent spectrum allocations
- carrier frequency relationships
- characteristics of any required training signals, such as timing, channel number, service type, and frequency of augmentation channel
- effect on existing population of receivers
- new channel group delay characteristics
- co-channel and adjacent channel
- new receiver distortion and selectivity characteristics
- sharing criteria for channels 14 - 20
- impact on Radio Astronomy Service on channel 37
- interference implications

Even if an optimized and comprehensive repacking of the VHF and UHF spectrum were indicated by such a study, it would have far reaching and significant impact. It would be difficult to implement. It would prematurely obsolete current receivers unless sufficient transition time were provided for their natural demise. It should be embraced only if there were absolutely no other alternative. A single-channel, receiver-compatible ATV system followed by future augmentation to HDTV with a second channel provides a very attractive alternative. This alternative also obviates the need for precipitous spectrum modification.

9. What would be the technical and economic impact on existing NTSC service if the Commission modified or eliminated the existing protection criteria?

Interference to a large number of NTSC receivers in the field can be anticipated, particularly at UHF. Without receiver improvements and a phase-in period, visible beats due to interference from new channels assigned to the previously "taboo" frequencies would occur. Any change in the protection criteria should await further studies, including tests on existing receivers. On the basis of the results of such a study, a scheduled modification of the protections may be possible.

QUESTIONS ON USE OF MICROWAVE FREQUENCIES

10. Should the Commission accommodate ATV in non-broadcast spectrum allocations? If so, in what portion of the spectrum and how much?

It is the David Sarnoff Research Center's position that ATV and, eventually, HDTV service should be accommodated in the UHF and VHF bands, in preference to terrestrial broadcasting in the 2.5-2.69 GHz, the 12.2-12.7 GHz or the 22-23 GHz bands. ATV service should emerge as an evolution of existing broadcast television services, so that the use of a new delivery medium would be justified only if there are compelling technical and economic benefits.

The major benefit offered by microwave broadcast is the relative availability of spectrum potentially needed for HDTV signals. This advantage is offset by serious technical problems such as rain fading, physical blockage, poor coverage, multipath, and interference, which are of greater concern in the context of high quality HDTV services than for conventional TV broadcasting. Accordingly, it is recommended that ATV be broadcast in the UHF/VHF bands, using spectrally efficient (6-12 MHz) ATV/HDTV signal formats.

NOTE: Questions 11 and 12 are answered jointly below.

11. What are the technical and economic advantages and disadvantages of this spectrum option under the various scenarios described above?

12. How well do the technical and economic advantages and disadvantages in this spectrum option compare with the other options described above?

The major technical/economic advantage of using microwave frequencies for terrestrial ATV broadcast is the greater availability of spectrum relative to VHF/UHF, permitting transmission of potentially wider bandwidth signals required for future HDTV systems. Current developments in ATV suggest, however, that good quality EDTV/HDTV can be delivered in a reasonably spectrum-efficient and compatible manner, consistent with evolutionary introduction of ATV in the current VHF/UHF broadcast bands. In addition, there are serious questions concerning the viability of ATV in the proposed microwave bands, requiring further technical and economic analysis.

The 22-23 GHz band is unsuitable for terrestrial broadcast because of the severe signal blockage and rain attenuation problems. At 12.2-12.7 GHz, transmission is technically feasible (as demonstrated by NHK[2], but is characterized by major technical difficulties due to rain fading, physical blockage, ghosting (multipath), poor coverage, and interference from BSS satellite services. In the 2.5-2.69 GHz frequency band, these problems are substantially less severe, so that MDS-type service is viable at moderate cost. MDS[3] experience, however, suggests that reception problems in this band require careful pointing and rigid installation of antennas. Even so, ghosting has been a major technical problem for MDS, sometimes requiring the introduction of signal-canceling antenna arrays.

ATV signals are, in general, less robust than conventional NTSC broadcast signals and therefore require transmission media with low signal fading or multipath. Low robustness of ATV signals is not a characteristic of a particular format but can be expected to be a general property in view of the high degree of signal compression required to accommodate a high-quality image in 6-12 MHz bandwidth. Initial analysis of candidate formats, such as MUSE or ACTV, confirm the need for channels free from multipath and

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2 T. Momoura, "SHF Terrestrial Broadcasting in Japan," *IEEE Trans. on Broadcasting,* Vol. BC-25, No. 4, Dec. 1979, pp. 147-151.

3 S. P. Lapin, "Television Broadcasting at Microwave Frequencies," *IEEE Trans. on Broadcasting,* Vol. BC-27, No. 3, Sept. 1981, pp. 55-59.

with high SNR. These requirements can best be approached by introducing ATV in the VHF/UHF bands in which the broadcasting industry has accumulated considerable experience in providing high signal quality.

In terms of economic considerations, use of microwave frequencies for ATV will require considerably greater investment than the VHF/UHF alternatives. Factors contributing to the higher cost for the broadcaster are the low coverage area (implying fewer viewers) per transmitting station, the need for high antenna installations, and the requirement for high effective radiated power to overcome signal fading. Subscriber cost will be increased by antenna installation issues and the need for a microwave receiver or microwave-to-UHF/VHF converter.

13. If ATV is implemented outside the conventional TV bands, should we also pursue proposals to adapt conventional TV to ATV? Is it worthwhile to pursue ATV at both UHF and microwave?

Should the Commission decide to permit ATV broadcast at microwave frequencies, simultaneous introduction of ATV in the conventional TV bands is still essential for the high market penetration required for eventual economic viability.

14. What technical problems, such as propagation or equipment development, could impede implementation of a terrestrial ATV service at 2.5 GHz, 12 GHz, 23 GHz or other portions of the spectrum?

Rain attenuation and signal blockage of terrestrial systems are likely to be insurmountable problems in the 22-23 GHz band. At 12.2-12.7 GHz, problems associated with signal blockage due to trees and buildings have been a major difficulty, even in satellite broadcasting services for which the antenna look angles are more favorable. Thus, technical difficulties with receiver antenna siting and multipath conditions are expected to impede implementation of terrestrial TV at 12 GHz. At 2.5-2.69 GHz, the problems are less severe, but even a small amount of multipath can negate the perceptual benefits of typical compressed ATV signals.

15. What is the impact of sharing non-broadcast spectrum with ATV on the non-broadcast services?

The effect of microwave ATV on non-broadcast services will depend upon the particular modulation methods employed for ATV signal distribution. Tests should be conducted in the 2.5-2.69 GHz region to establish the effect of potential HDTV transmission formats and shared non-broadcast services on each other prior to any serious consideration of an ATV allocation in this band.

QUESTIONS RELATED TO ATV AND THE UHF-TABOOS

NOTE: Questions 8.b. and 16 - 21 are answered jointly below.

8.b. How much additional bandwidth could be made available for ATV, and what would be the interference implications if the Commission modified or eliminated some or all of the UHF taboo channel protection standards?

16. The present taboos were adopted in 1952 and have remained unchanged since that time. What taboos should be eliminated or modified and what impact would this have on existing television service?

17. In reevaluating the effect of taboos generally, what percentage of viewers should be protected?

18. Are the conclusions concerning the "VHF reference" criteria described in this proceeding justified? Should the taboos be modified as suggested in this proceeding?

19. Because of the taboos, only 9 (at most) UHF channels can be assigned to any given city.

a. To what extent could broadcasters take advantage of the "gaps" in the allocation table to transmit auxiliary information for advanced TV systems?

b. Should new assignments made possible by elimination or modification of taboos be reserved for advanced TV system use, opened for licensing to new full service stations, or used for other purposes?

20a. How might future improvements in television receivers affect susceptibility to taboo frequencies?

b. Are advanced TV signals (including any auxiliary signals or augmentation channels) likely to be more, or less, susceptible to current taboo frequencies? Will new taboo frequencies arise?

c. Are changes in receiver designs likely to cost-effectively reduce the susceptibility of receivers to taboo frequencies for NTSC signals?

d. What are the anticipated costs of taboo-immune TV receivers and the time frame for significant market penetration?

21. Should the Commission take action now to encourage reduced generation of and susceptibility to taboos, either on channels used for NTSC or auxiliary advanced TV signals? If so, what action is appropriate: e.g. spectrum allocation, interference, or other?

General Comments on Modification of UHF Taboos

Relaxation of UHF taboos is necessary to make additional spectrum available for future ATV needs. This relaxation must be accomplished according to a studied and phased plan so that the effects on broadcasters, manufacturers, and viewers are understood and controlled. The Commission itself stated at Paragraph 79 of the Inquiry: "Many matters raised in this inquiry will have to be resolved <u>before</u> the taboos can be modified." The Commission should move cautiously on any changes of existing taboos since existing receivers in the field have been designed for cost-performance optimization with the taboos in mind. Recent FCC rulings on UHF noise figures may have had impact on tuner performance with regard to taboos; in general, devices chosen for lower noise are likely to be more susceptible to intermodulation distortion. The introduction of Multichannel Television Sound may also contribute to increased receiver vulnerability to disturbances.

FCC Rule Section 73.610, which specifies the taboos, was introduced in 1952 on a sound technical foundation based on state-of-the-art receiver design[4]. As indicated in the Inquiry (Sections 68-71) several efforts have been made to reevaluate the taboos[5], including demonstrations of improved receiver designs. These reevaluations remain inconclusive, partly because of the complexity of the issues, which involve receiver cost-performance evaluations, assessment of how much and how many viewers might be disturbed by modification of the taboos, and the uncertainties in predicting the potential increase in assignments as the taboos are modified.

The use of "VHF reference criteria" is an insufficient basis for modifying UHF taboos. This approach does not take into account antenna or propagation characteristics. A more complete systems accounting is needed, which would include the VHF reference criteria as planning factors.

This Inquiry broadens the issue of modifying the taboos to include channel assignment to non-NTSC-type ATV augmentation channels. The potential disturbance that these currently unspecified signals may cause in reception of currently assigned channels is not known. A further issue is the disturbance that existing assigned channels may cause in reception of ATV augmentation channels, e.g., interference caused by radiation from local oscillators of existing receivers, co-channel interference, etc.

While worthy studies[6] have been made, the introduction of new factors, such as the radiation and reception of ATV augmentation signals, suggests that a thorough study of the use of the UHF broadcast spectrum be initiated as soon as possible.

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4 Sixth Report and Order, Docket #9736 FCC 148 (1952)

5 Notice of Inquiry, Docket #20485 FCC 2nd 411 (1975)

6 Advanced Technology UHF Receiver Study Part 2: "Effective on UHF Television Allotments," FCC/OST R84-1, March 1985.

Potential Receiver Improvements

In Section III.D. of the Inquiry and associated references, one finds an excellent discussion of taboos, the history behind their establishment, and the development of television front ends using advanced technology.

The David Sarnoff Research Center's laboratory experience, combined with the knowledge published by Texas Instruments and RF Monolithics (cited in the Inquiry), indicates that the use of double conversion tuners in future television receiver designs could be expected to eliminate many UHF taboos. The picture image taboo (n ± 15), the sound image taboo (n ± 14), the local oscillator (LO) radiation taboo (n ± 7), the intermediate frequency (IF) taboo (n ± 8), and the half IF taboo (n ± 4) can be eliminated by using a double conversion front end.

The first IF choice of such a double conversion tuner is critical to avoid generating new taboos. Susceptibility to existing signals will also constrain this choice. The generation of internal spurious responses may preclude some choices. Ideally, the first IF should be placed as high in frequency as possible so that the existing taboos can be eliminated and new taboos are not generated. Practical constraints limit the upper bound of the first IF choice.

In addition to changing to a double conversion tuner architecture, the following technologies could be applied to achieve a taboo-robust tuner design:

- SAW filters in the first and second IFs
- double balanced mixers to reduce IM distortion
- back-to-back tuning diodes to reduce IM distortion
- larger transistor structures to reduce IM distortion
- input filtering with high side tracking traps at the image frequency
- intelligent and adaptive front-end selectivity to further attenuate undesired signals

- improved construction/fabrication techniques to integrate circuitry and shielding into a uniform structure to control radiation and coupling
- additional tuned circuits to improve selectivity

Some of these approaches would increase the noise figure. Some noise figure performance can be traded off in favor of improved distortion (taboo) performance. Lower loss tuning diodes to reduce noise figure can be expected at increased cost and increased intermodulation distortion (IM).

SAW filters properly specified at both the first IF and the second IF would be needed to eliminate the ±1 and ±2 channel IM taboos. Adaptive input filtering, which uses low distortion devices, is the key to removing the remaining close-in intermodulation taboos (n ±2, ±3, ±4 and ±5). It is possible to replace the first SAW IF filter with a frequency-agile filter to achieve better control of internal spurious signal generation.

The total impact of providing upgraded tuner performance is not clear, however. Other factors, such as the co-channel protection ratio, could override any gains achieved. A total system approach must be taken to understand the problem fully. Improved planning techniques that include issues such as co-location of transmitters, utilization of shaped antenna patterns, and a comprehensive interference analysis, should be utilized. ATV signals may require more channel bandwidth or an augmentation channel. At worst, two tuning systems and two IFs would be required. Depending on the factors listed elsewhere (see 8.c. in these Comments), careful study of each ATV proposal and allocation plan must be carried out to determine if new taboos are generated and to estimate to what extent a new ATV signal would be impacted by the current taboos.

Recommended Study

A comprehensive technical study with the objective of replacing the 1952 plan with a new plan for UHF spectrum allocation and uses should be initiated immediately. This study should include the development of a computer model of television broadcasting that could be adapted to regional conditions such as terrain, population distribution, etc. Important inputs and outputs are taboos, interference levels, transmitter power and antennas, receiver antennas, receiver model parameters, etc. The study should also include analysis and tests, particularly related to the design of cost-effective improvements in receivers with regard to relaxed taboos, improved noise figures, coverage, etc.

A considerable amount of data and knowledge regarding these matters is already available for broadcasting of NTSC television. New uses of the spectrum, particularly for ATV augmentation signals, will require new analyses. Augmentation signals will be tuned by special receivers, which could be designed to be more immune to disturbances at taboo frequencies than existing receivers.

Time Frame for a New UHF Allocation Plan

Phase I (two years) Study and specify a plan for modifying the taboos at the earliest possible time. An important element of the plan is a software package for a UHF allocation plan to replace the taboos (FCC Rule Section 73.610) and other criteria for "filling in gaps."

Phase II Design and build television receivers according to the new taboo plan.

Phase III Introduce new sets to the consumer market. Reduce or eliminate taboos according to the plan when enough time has passed that only a small number of home TV receivers will be disturbed.